SIEMENS

SIMATIC

ET 200SP
Analog input module
F-AI 4xI 0(4)..20mA 2-/4-wire HF
(6ES7136-6AA00-0CA1)

Manual

Original operating instructions

08/2018

A5E41448857-AB

Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

⚠DANGER

indicates that death or severe personal injury **will** result if proper precautions are not taken.

⚠WARNING

indicates that death or severe personal injury **may** result if proper precautions are not taken.

⚠CAUTION

indicates that minor personal injury can result if proper precautions are not taken.

NOTICE

indicates that property damage can result if proper precautions are not taken.

If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used. A notice warning of injury to persons with a safety alert symbol may also include a warning relating to property damage.

Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

Proper use of Siemens products

Note the following:

⚠WARNING

Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

Trademarks

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Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

Siemens AG
Division Digital Factory
Postfach 48 48
90026 NÜRNBERG
GERMANY

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Preface

Purpose of the documentation

This manual supplements the system manual Distributed I/O System ET 200SP (http://support.automation.siemens.com/WW/view/en/58649293).

Functions that affect the system in general are described in the system manual.

The information in this manual and the system/function manuals provide support when you commission the system.

A description of the F-system SIMATIC Safety can be found in the programming and operating manual SIMATIC Safety – Configuring and Programming (http://support.automation.siemens.com/WW/view/en/54110126).

Conventions

CPU: When the term "CPU" is used hereafter, it refers to both the CPUs of the S7-1200/1500 automation system and CPUs of the ET 200SP distributed I/O system.

STEP 7: In this documentation, "STEP 7" is used as a synonym for all versions of the configuration and programming software " (STEP 7 TIA Portal)".

Note the following identified notes:

Note

A note includes important information on the product described in the documentation, on handling the product or on the part of the documentation to which you ought to pay special attention.

Standards

You can find a dated reference to the respective standards in the certificate (https://support.industry.siemens.com/cs/ww/en/view/57141281) or in the EC Declaration of Conformity (https://support.industry.siemens.com/cs/ww/en/view/71764057) for the F-module.

Certified versions

You can find the certified product and firmware versions in annex 1 of the report on the TÜV certificate (https://support.industry.siemens.com/cs/ww/en/view/57141289).

Recycling and disposal

For environmentally friendly recycling and disposal of your old equipment, contact a certified electronic waste disposal company and dispose of the equipment according to the applicable regulations in your country.

Important note for maintaining the operational safety of your system

WARNING

The operators of systems with safety-related characteristics must adhere to specific operational safety requirements. The supplier is also obliged to comply with special product monitoring measures. Siemens informs system operators in the form of personal notifications about product developments and properties which may be or become important issues in terms of operational safety.

You should subscribe to the corresponding notifications in order to obtain the latest information and to allow you to make any necessary modifications to your system.

Log on to Industry Online Support. Follow the links below and click on "Email on update" on the right-hand side in each case:

- SIMATIC S7-300/S7-300F (https://support.industry.siemens.com/cs/products?pnid=13751&lc=en-WW)
- SIMATIC S7-400/S7-400H/S7-400F/FH (https://support.industry.siemens.com/cs/products?pnid=13828&lc=en-WW)
- SIMATIC WinAC RTX (F) (https://support.industry.siemens.com/cs/ww/en/ps/13915)
- SIMATIC S7-1500/SIMATIC S7-1500F (https://support.industry.siemens.com/cs/products?pnid=13716&lc=en-WW)
- SIMATIC S7-1200/SIMATIC S7-1200F (https://support.industry.siemens.com/cs/products?pnid=13683&lc=en-WW)
- Distributed I/O (https://support.industry.siemens.com/cs/products?pnid=14029&lc=en-WW)
- STEP 7 (TIA Portal) (https://support.industry.siemens.com/cs/products?pnid=24471&lc=en-WW)

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, systems, machines and networks.

In order to protect plants, systems, machines and networks against cyber threats, it is necessary to implement – and continuously maintain – a holistic, state-of-the-art industrial security concept. Siemens' products and solutions constitute one element of such a concept.

Customers are responsible for preventing unauthorized access to their plants, systems, machines and networks. Such systems, machines and components should only be connected to an enterprise network or the internet if and to the extent such a connection is necessary and only when appropriate security measures (e.g. firewalls and/or network segmentation) are in place.

For additional information on industrial security measures that may be implemented, please visit (https://www.siemens.com/industrialsecurity).

Siemens' products and solutions undergo continuous development to make them more secure. Siemens strongly recommends that product updates are applied as soon as they are available and that the latest product versions are used. Use of product versions that are no longer supported, and failure to apply the latest updates may increase customers' exposure to cyber threats.

To stay informed about product updates, subscribe to the Siemens Industrial Security RSS Feed under (https://www.siemens.com/industrialsecurity).

Table of contents

Documentation guide

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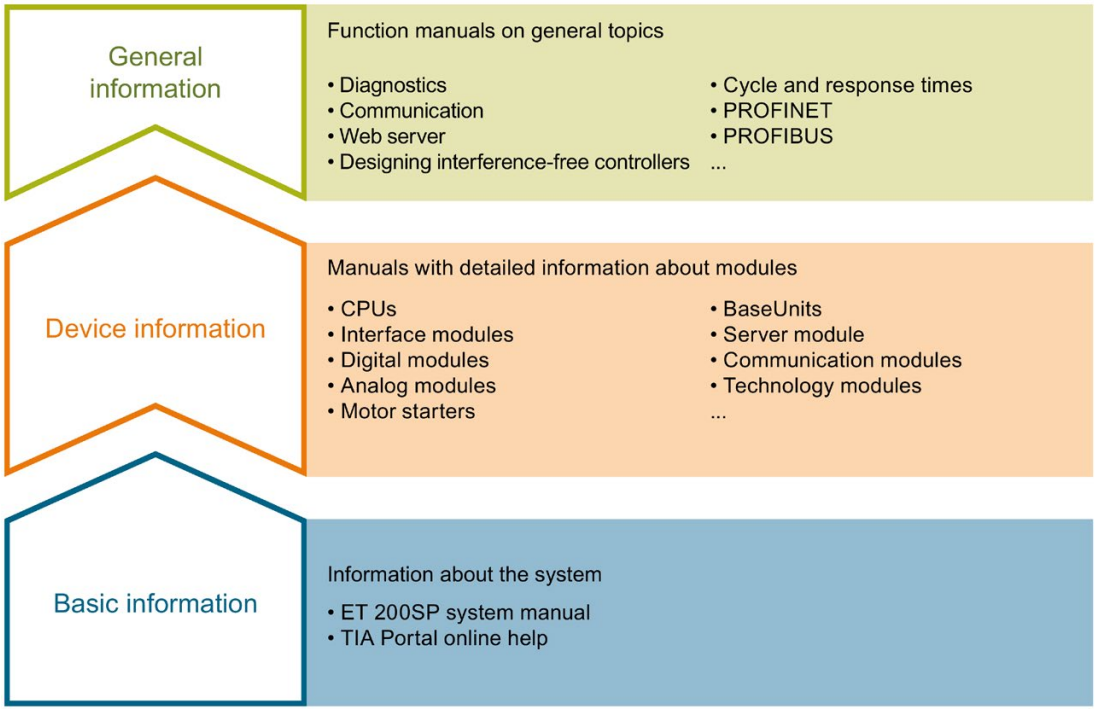
The documentation for the SIMATIC ET 200SP distributed I/O system is arranged into three areas.
This arrangement enables you to access the specific content you require.



Basic information

The system manual describes in detail the configuration, installation, wiring and commissioning of the SIMATIC ET 200SP. distributed I/O system. The STEP 7 online help supports you in the configuration and programming.

Device information

Product manuals contain a compact description of the module-specific information, such as properties, wiring diagrams, characteristics and technical specifications.

General information

The function manuals contain detailed descriptions on general topics regarding the SIMATIC ET 200SP distributed I/O system, e.g. diagnostics, communication, Web server, motion control and OPC UA.

You can download the documentation free of charge from the Internet (https://support.industry.siemens.com/cs/ww/en/view/109742709).

Changes and supplements to the manuals are documented in a Product Information.

You can download the product information free of charge from the Internet (https://support.industry.siemens.com/cs/us/en/view/73021864).

Manual Collection ET 200SP

The Manual Collection contains the complete documentation on the SIMATIC ET 200SP distributed I/O system gathered together in one file.

You can find the Manual Collection on the Internet (http://support.automation.siemens.com/WW/view/en/84133942).

"mySupport"

With "mySupport", your personal workspace, you make the most of your Industry Online Support.

In "mySupport" you can store filters, favorites and tags, request CAx data and put together your personal library in the Documentation area. Furthermore, your data is automatically filled into support requests and you always have an overview of your current requests.

You need to register once to use the full functionality of "mySupport".

You can find "mySupport" in the Internet (https://support.industry.siemens.com/My/ww/en).

"mySupport" - Documentation

In the Documentation area of "mySupport", you have the possibility to combine complete manuals or parts of them to make your own manual.
You can export the manual in PDF format or in an editable format.

You can find "mySupport" - Documentation in the Internet (http://support.industry.siemens.com/My/ww/en/documentation).

"mySupport" - CAx Data

In the CAx Data area of "mySupport", you can have access the latest product data for your CAx or CAe system.

You configure your own download package with a few clicks.

In doing so you can select:

- Product images, 2D dimension drawings, 3D models, internal circuit diagrams, EPLAN macro files
- Manuals, characteristics, operating manuals, certificates
- Product master data

You can find "mySupport" - CAx Data in the Internet (http://support.industry.siemens.com/my/ww/en/CAxOnline).

Application examples

The application examples support you with various tools and examples for solving your automation tasks. Solutions are shown in interplay with multiple components in the system - separated from the focus in individual products.

You can find the application examples on the Internet (https://support.industry.siemens.com/sc/ww/en/sc/2054).

TIA Selection Tool

With the TIA Selection Tool, you can select, configure and order devices for Totally Integrated Automation (TIA).
This tool is the successor of the SIMATIC Selection Tool and combines the known configurators for automation technology into one tool.
With the TIA Selection Tool, you can generate a complete order list from your product selection or product configuration.

You can find the TIA Selection Tool on the Internet (http://w3.siemens.com/mcms/topics/en/simatic/tia-selection-tool).

SIMATIC Automation Tool

You can use the SIMATIC Automation Tool to run commissioning and maintenance activities simultaneously on various SIMATIC S7 stations as a bulk operation independently of the TIA Portal.

The SIMATIC Automation Tool provides a multitude of functions:

- Scanning of a PROFINET/Ethernet network and identification of all connected CPUs
- Address assignment (IP, subnet, gateway) and station name (PROFINET device) to a CPU
- Transfer of the data and the programming device/PC time converted to UTC time to the module
- Program download to CPU
- Operating mode switchover RUN/STOP
- Localization of the CPU by means of LED flashing
- Reading out CPU error information
- Reading the CPU diagnostic buffer
- Reset to factory settings
- Updating the firmware of the CPU and connected modules

You can find the SIMATIC Automation Tool on the Internet (https://support.industry.siemens.com/cs/ww/en/view/98161300).

PRONETA

With SIEMENS PRONETA (PROFINET network analysis), you analyze the plant network during commissioning. PRONETA features two core functions:

- The topology overview independently scans PROFINET and all connected components.
- The IO check is a fast test of the wiring and the module configuration of a system.

You can find SIEMENS PRONETA on the Internet (https://support.industry.siemens.com/cs/ww/en/view/67460624).

SINETPLAN

SINETPLAN, the Siemens Network Planner, supports you in planning automation systems and networks based on PROFINET. The tool facilitates professional and predictive dimensioning of your PROFINET installation as early as in the planning stage. In addition, SINETPLAN supports you during network optimization and helps you to exploit network resources optimally and to plan reserves. This helps to prevent problems in commissioning or failures during productive operation even in advance of a planned operation. This increases the availability of the production plant and helps improve operational safety.

The advantages at a glance

- Network optimization thanks to port-specific calculation of the network load
- Increased production availability thanks to online scan and verification of existing systems
- Transparency before commissioning through importing and simulation of existing STEP 7 projects
- Efficiency through securing existing investments in the long term and optimal exploitation of resources

You can find SINETPLAN on the Internet (https://www.siemens.com/sinetplan).

Product overview

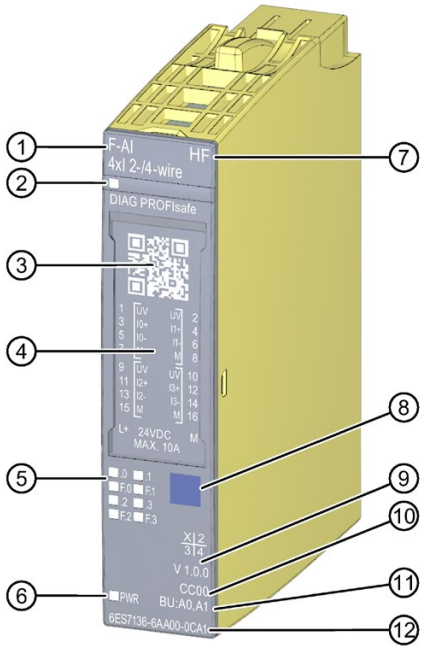
2

2.1 Properties

Article number

6ES7136-6AA00-0CA1

View of the module



① Module type and name
② LED for diagnostics
③ 2D matrix code
④ Wiring diagram
⑤ LEDs for channel status
⑥ LED for supply voltage
⑦ Function class
⑧ Color coding module type
⑨ Function and firmware version
⑩ Color code for selecting the color identification labels
⑪ BU type
⑫ Article number

Figure 2-1 View of the F-AI 4xI 0(4)..20mA 2-/4-wire HF module

Properties

The module has the following technical properties:

- Fail-safe module
- PROFIsafe

- Supports the "RIOforFA-Safety" profile on F-CPUs S7-1200/1500.
- PROFIsafe address type 2
- 4 analog inputs with electrical isolation between channels and the backplane bus (up to SIL3/Cat.4/PLd)
- Measuring ranges: 0..20 mA and 4..20 mA
- Resolution: 16 bits including sign
- Short circuit-proof power supply for 2-wire or 4-wire transmitter
- Supply voltage L+
- External sensor supply possible
- Assignable diagnostics
- Diagnostics display (DIAG, red/green LED)
- Status display for each input (green LED)
- Error display for each input (red LED)
- Diagnostics
  - e.g., short-circuit, channel-specific
  - e.g. supply voltage missing, module-specific
- Channel- and module-wide passivation

The module supports the following functions:

- Firmware update
- I&M identification data
- Value status

WARNING

The fail-safe performance characteristics in the technical specifications apply for a mission time life of 20 years and a repair time of 100 hours. If a repair within 100 hours is not possible, remove the respective module from the BaseUnit or switch off its supply voltage before 100 hours expires.

The module switches off independently after the 100 hours have expired.

Follow the repair procedure described in section Diagnostic messages (Page 58).

Note

Cyclic reading of I&M data

Cyclic reading of I&M data can affect the timing of the F-modules. You should therefore avoid short read cycles of less than 500 ms.

Accessories

You can order the following accessories separately:

- Labeling strips
- Color identification labels
- Reference identification label
- Shield connector
- Electronic coding element as spare part (article number 6ES7193-6EF00-1AA0)

You can find additional information about accessories in the Distributed I/O System ET 200SP (http://support.automation.siemens.com/WW/view/en/58649293) System Manual.

Connecting

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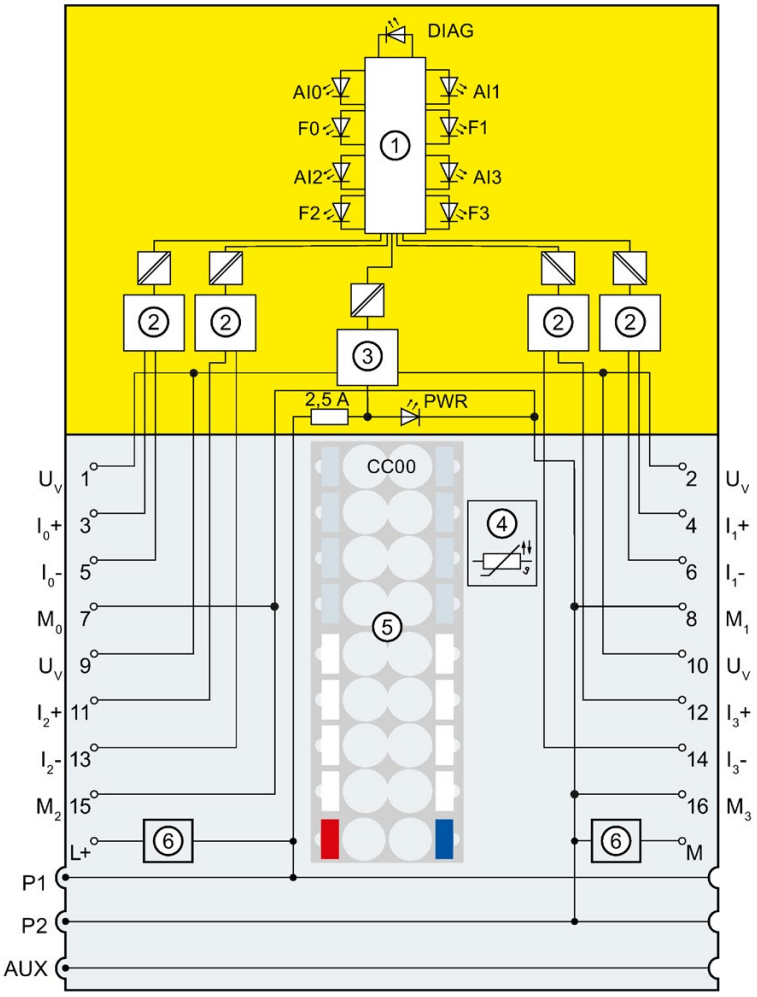
3.1 Wiring and block diagram

This section provides the block diagram of the F-AI 4xI 0(4)..20mA 2-/4-wire HF analog input module with the terminal assignment.

You can find additional information about wiring BaseUnits in the Distributed I/O System ET 200SP (http://support.automation.siemens.com/WW/view/en/58649293) System Manual.

Block diagram

The following figure shows the block diagram of the F-AI 4xI 0(4)..20mA 2-/4-wire HF analog input module on the BaseUnit BU type A0/A1.



①	Backplane bus interface	U_V	Sensor supply
②	Analog-to-digital converter (ADC)	M	Supply voltage ground
③	Sensor supply/reverse polarity protection	M_n	Ground to channel n
④	Temperature measurement for BU type A1 only (the function cannot be used for this module.)	L+	24 V DC (infeed only with light-colored BaseUnit)
⑤	Color-coded label with color code CC00 (optional)	P1, P2, AUX	Internal self-assembling voltage buses Connection to left (dark-colored BaseUnit) Connection to left interrupted (light-colored BaseUnit)
⑥	Filter connection supply voltage (available with light-colored BaseUnit only)	DIAG	Diagnostics LED (green, red)
I_n+	Current input positive, channel n	AI0, AI1, AI2, AI3	Channel status LED (green)
I_n-	Current input negative, channel n	F0, F1, F2, F3	Channel fault LED (red)
		PWR	Power LED (green)

Figure 3-1 Block diagram

Sensor supply

WARNING

Voltage dips and voltage fluctuations of the voltage supply are not buffered by the F-module and, thus, affect the sensor supply.

This can cause the measured value to be false and must be taken into account when determining the safety function.

To ensure that the sensor functions problem-free, we recommend one of the following options:

- You can avoid voltage dips by using a voltage supply according to the NAMUR recommendation NE 21.

or

- Use a transducer with an appropriate battery backup or diagnostics.

Recommendation: Internal sensor supply

You are strongly advised to use the short circuit-proof internal sensor supply of the F-module. This internal sensor supply is monitored and its status is indicated by the Fn LED. The input is also protected in the event of short-circuits in the wiring or at the sensor.

Note

The internal sensor supply is switched off in case of a short circuit to ground or during power-up in the event of short circuit to L+.

The sensor supply is also switched off at input currents > 35 mA.

A check is made approximately 1 minute later to determine if the error has gone.

Note

Behavior of process values and diagnostics evaluation

Sensor startup during module startup:

After the internal sensor supply is activated, the evaluation of wire break and underflow diagnostics is suppressed for 3 seconds. During this time, the module makes the secure process data 0 available at all channels. This suppresses a possible wire break or underflow diagnostics caused by the sensor startup. If the sensor startup is not yet complete after the 3 seconds have elapsed, it is possible that the module might detect wire break or underflow and passivate the affected channel. In this case, the channel fault must be acknowledged during startup.

Sensor startup during operation:

If a sensor startup takes place during operation, e.g. the sensor supply is reactivated after a short-circuit, all analog values are invalid and wire break or underflow diagnostics can occur on the sensors connected to the internal sensor supply.

External/internal sensor supply

The figures in section "Applications of the F-I/O module (Page 40)" show how you can supply power to the sensors via an external sensor supply (for example, from another module).

WARNING

If there is a short-circuit from L+ to Mn+, the input resistors could be destroyed, depending on the selected interconnection type.

You can avoid this problem through proper wiring and use of the internal sensor supply. When an external sensor supply is used, other suitable measures are necessary to protect the input resistors (e.g. external fast 50 mA fuse in the input circuit of the F-module).

WARNING

External sensor supply

If you use an external sensor supply, you need to take into consideration the voltage dips and voltage fluctuations when determining the safety function.

To ensure that the sensor functions problem-free, we recommend one of the following options:

- Use a transducer with an appropriate battery backup or diagnostics.

  or
- Use a **redundant** external sensor supply

  or
- **Monitor** the external sensor supply for undervoltage/overvoltage, including shutdown of the sensor supply in the event of a fault (single channel for SIL2; two-channel for SIL3).

Parameters/address space

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4.1 Measurement types and measuring ranges

The following table shows the measurement types and the respective measuring range.

Table 4- 1 Measurement types and measuring ranges

Measurement type	Measuring range	Resolution
Current	0 to 20 mA (2-wire and 4-wire transducer) 4 to 20 mA (2-wire and 4-wire transducer)	16 bits including sign 16 bits including sign

You can find the tables of the measuring ranges as well as overflow, overrange, etc. in the Appendix Representation of analog values (Page 71).

4.2 Parameters

Parameters for F-AI 4xI 0(4)..20mA 2-/4-wire HF

WARNING

Diagnostics functions should be activated or deactivated in accordance with the application, see section Applications of the F-I/O module (Page 40).

The following parameters are possible:

Table 4- 2 Configurable parameters

Parameters	Value range	Default	Parameter reassignment in RUN	Scope
F-parameters:				
Manual assignment of the F-monitoring time	• Disable • Enable	Disable	No	Module
F-monitoring time	1 to 65535 ms	150 ms	No	Module
F-source address	1 to 65534	depends on parameter assignment of F-CPU	No	Module
F-destination address	1 to 65534	suggested by F-system	No	Module
F-parameter signature (without address)	0 to 65535	calculated by F-system	No	Module

Parameters	Value range	Default	Parameter reassignment in RUN	Scope
Behavior after channel faults	• Passivate entire module • Passivate channel	Passivate channel	No	Module
Reintegration after channel fault	• Adjustable • All channels automatically • All channels manually	(S7-300/400) Adjustable (S7-1200/1500) All channels manually	No	Module
F-I/O DB manual number assignment	• Disable • Enable	Disable	No	Module
F-I/O DB number	—	suggested by F-system	No	Module
F-I/O DB name	—	suggested by F-system	No	Module
AI parameters				
Interference frequency suppression	• 50 Hz • 60 Hz	50 Hz	No	Module
Channel parameters:				
Channel n				
Sensor evaluation	• 1oo1 evaluation (max. SIL3/Cat.3/PLd) • 1oo2 evaluation (max. SIL3/Cat.4/PLe)	1oo1 evaluation (max. SIL3/Cat.3/PLd)	No	Channel
Standard value	• MIN • MAX	MIN	No	Channel
Discrepancy time *	100 to 30000 ms	100 ms	No	Channel
Tolerance window %, absolute	2.0 to 20.0%	5.0%	No	Channel
Tolerance window %, relative	2.0 to 20.0%	5.0%	No	Channel
Activated	• Disable • Enable	Enable	No	Channel
Channel fault acknowledgment	• Manual • Automatic The value range offered depends on the F-CPU in use and on the configuration of the F-parameter "Reintegration after channel fault".	(S7-300/400) Parameter is not supported (S7-1200/1500) Manual	No	Channel
Measuring range	• 0 to 20 mA • 4 to 20 mA	4 to 20 mA	No	Channel

Parameters	Value range	Default	Parameter reassignment in RUN	Scope
Diagnostics: Wire break **	• Disable • Enable	Enable	No	Channel
Smoothing	• 1 • 2 • 4 • 8 • 16 • 32 • 64	1	No	Channel

* See formula under Parameter assignment of discrepancy analysis for 1oo2 evaluation (Page 27)

* Can only be set with 4 to 20 mA measuring range

4.3 Explanation of parameters

4.3.1 F-parameters

You must assign the PROFIsafe address (F-destination address together with F-source address) to the F-module before you put it into operation.

- You define the F-source address using the "Base for PROFIsafe addresses" parameter in the F-CPU.
- An F-destination address unique throughout the CPU is automatically assigned for each F-module. You can manually change the F-destination addresses set in the hardware configuration.

You can find information on F-parameters for the F-monitoring time, the PROFIsafe addressing (F-source address, F-destination address) and the F-I/O DB in the manual SIMATIC Safety - Configuring and Programming (http://support.automation.siemens.com/WW/view/en/54110126).

4.3.2 Parameters of the channels

4.3.2.1 Interference frequency suppression

Here you set the interference frequency suppression for the line frequency:

- 50 Hz
- 60 Hz

You can find additional information on this in the Analog value processing function manual (https://support.industry.siemens.com/cs/ww/en/view/67989094).

4.3.2.2 Evaluation of the sensors

Overview

Here you select the type of sensor evaluation:

- "1oo1 evaluation (max. SIL3/Cat.3/PLd)"
- "1oo2 evaluation (max. SIL3/Cat.4/PLe)"

If you do not want to measure with a channel or channel pair, disable the channel or the channel pair.

1oo1 evaluation (max. SIL3/Cat.3/PLd)

With the 1oo1 evaluation, there is one sensor, and it is connected to the F-module via a single channel.

1oo2 evaluation (max. SIL3/Cat.4/PLe)

With the 1oo2 evaluation, two input channels are occupied by:

- Two single-channel sensors
- One two-channel sensor

Note that in 1oo2 evaluation, two channels are combined into a channel pair.

Achievable safety class

Depending on the selected sensor evaluation, you achieve the following safety classes with a sensor that is qualified accordingly:

- SIL3/Cat.3/PLd for "1oo1 evaluation" or
- SIL3/Cat.4/PLe for "1oo2 evaluation"

See also

Parameter assignment of discrepancy analysis for 1oo2 evaluation (Page 27)

4.3.2.3 Standard value

Function

If you have selected "1oo2 evaluation (max. SIL3/Cat.4/PLe)", you can choose for each input channel pair which of the two F-CPU values is provided.

- "MIN": the lesser of the two values.
- "MAX": the greater of the two values.

During a discrepancy between the two input channels, the last valid standard value prior to the occurrence of the discrepancy is made available to the F-CPU.

4.3.2.4 Discrepancy time

Function

If you have selected "1oo2 evaluation (max. SIL3/Cat.4/PLe)", you can enter the discrepancy time for each channel pair here in milliseconds.

The discrepancy time does not start until the standard value is outside the assigned tolerance window (relative or absolute). If the two redundant input channels of the channel pair differ by more than the specified tolerance and for longer than the specified discrepancy time but no longer than the duration of the maximum response time, the F-module detects a discrepancy error and triggers a diagnostic interrupt. If the input channels fall below the specified tolerance prior to expiration of the discrepancy time (input channels are no longer discrepant), the discrepancy time is cleared and is restarted only when a new discrepancy is detected.

You can find additional information about configuring the discrepancy analysis under Parameter assignment of discrepancy analysis for 1oo2 evaluation (Page 27).

A discrepancy error is handled by the safety program in the same way as a channel fault. Additional information is available in the SIMATIC Safety – Configuring and Programming (http://support.automation.siemens.com/WW/view/en/54110126) manual.

4.3.2.5 Tolerance window %, absolute

Function

If you have selected "1oo2 evaluation (max. SIL3/Cat.4/PLe)", you can enter the size of a tolerance window for the discrepancy here for the channel pair. You specify the tolerance window as a percentage of the full-scale value. The reference value is the full-scale value, i.e. 20 mA. The entered value is rounded to one decimal place.

If two redundant input channels of the channel pair differ by more than the tolerance specified here and for longer than the specified discrepancy time, the F-module detects a discrepancy error and triggers a diagnostic interrupt.

For more information regarding setting the tolerance window, refer to Parameter assignment of discrepancy analysis for 1oo2 evaluation (Page 27).

Example

You have assigned the following:

- The "Tolerance window % absolute" 10%
- The measuring range 0..20 mA
- A discrepancy time of 100 ms

The input channels may differ from the configured discrepancy time (100 ms) up to the max. reaction time for a time window with a difference of more than 2 mA.

See also

Discrepancy time (Page 24)

4.3.2.6 Tolerance window %, relative

Function

If you have selected "1oo2 evaluation (max. SIL3/Cat.4/PLe)", you can enter the size of a tolerance window for the discrepancy here for each channel pair. You specify the tolerance window as a percentage of the assigned standard value. The entered value is rounded to one decimal place.

If two redundant input channels of the channel pair differ by more than the tolerance specified here and for longer than the specified discrepancy time, the F-module detects a discrepancy error and triggers a diagnostic interrupt.

The two parameters "Tolerance window % absolute" and "Tolerance window % relative" are combined. The "Tolerance window % absolute" parameter is decisive in case of low process values.

For more information regarding setting the tolerance window, refer to Parameter assignment of discrepancy analysis for 1oo2 evaluation (Page 27).

Example

You have assigned the following:

- The "tolerance window % relative" is set at 10%
- A measuring range of 0 to 20 mA
- A discrepancy time of 200 ms
- A unit value of 20 mA

The input channels may differ from the configured discrepancy time (200 ms) up to the max. reaction time for a time window with a difference of more than 2 mA.

See also

Discrepancy time (Page 24)

4.3.2.7 Parameter assignment of discrepancy analysis for 1oo2 evaluation

Operating principle of discrepancy analysis

A discrepancy analysis is performed with a configured 1oo2 evaluation. **Smoothed** process values are used for the discrepancy analysis.

An assignable tolerance window is formed around the process value that represents the instantaneous standard value (value that is signaled to the F-CPU).

The tolerance window is formed relative to the process value or as an absolute value relative to the measuring range end value. Relative and absolute tolerance windows are combined.

If the process value does not represent the standard value at an instant and is within the tolerance window, **no** discrepancy exists.

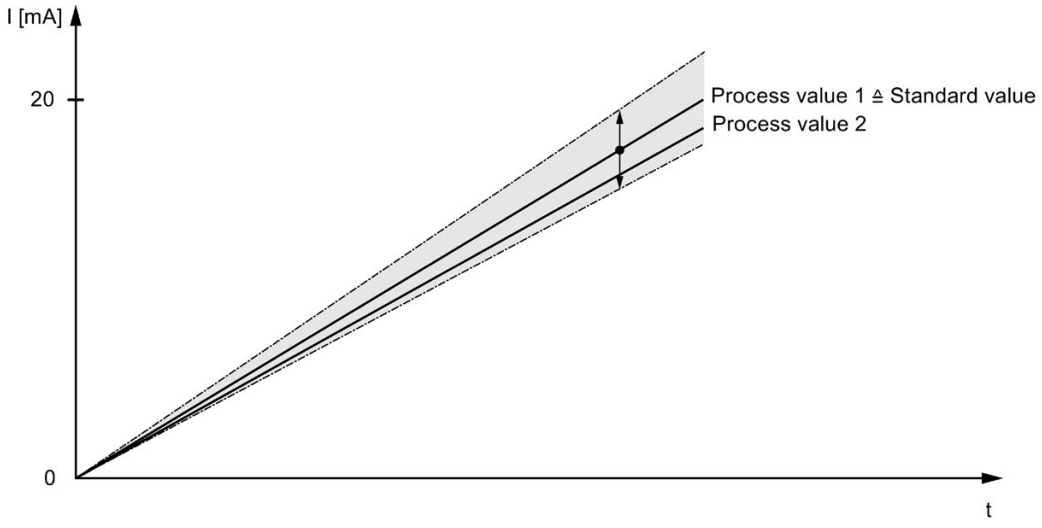


Figure 4-1 Example of a relative tolerance window *without* discrepancy (parameter assignment: standard value = MAX)

If the process value does not represent the standard value at an instant but is outside the tolerance window, a discrepancy exists.

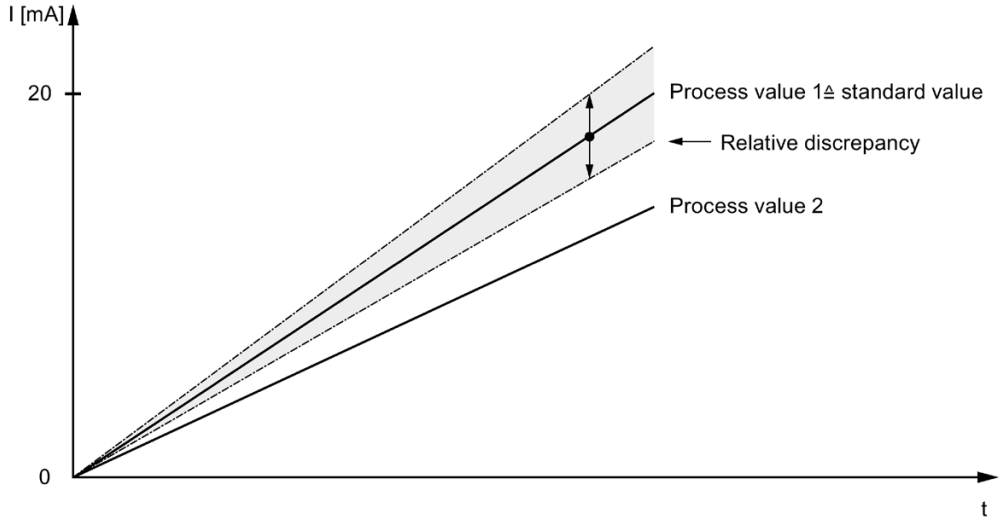


Figure 4-2 Example of a relative tolerance window *with* discrepancy (parameter assignment: standard value = MAX)

The assigned discrepancy time starts as soon as a discrepancy is detected. The discrepancy time runs as long as the discrepancy exists.

- During a discrepancy between the two input channels, the last valid standard value prior to occurrence of the discrepancy is signaled to the F-CPU.

  If the input channels fall below the specified tolerance prior to expiration of the discrepancy time (input channels are no longer discrepant), the discrepancy time is cleared and is restarted only when a new discrepancy is detected.

- There is no valid old value after startup. If the discrepancy is detected during this time, $7FFF_H$ is output for S7-300/400 F-CPUs or 0 is output for S7-1200/1500 F-CPUs and the discrepancy time is started.

  If there is no longer a discrepancy between the input channels when the discrepancy time expires, the standard value is output.

If the discrepancy time has expired, an error is signaled and the process value is set to $7FFF_H$ for S7-300/400 F-CPUs or 0 for S7-1200/1500 F-CPUs. In the PII, the substitute value 0 is set for the safety program.

A discrepancy error is handled by the safety program in the same way as a channel fault. Additional information is available in the STEP 7 Safety – Configuring and Programming (http://support.automation.siemens.com/WW/view/en/54110126) manual.

Configuring the discrepancy analysis parameters

The following four parameters for the discrepancy analysis are assigned for each channel pair:

- Discrepancy time
- Standard value
- Tolerance window %, absolute
- Tolerance window %, relative

"Discrepancy time" parameter

If the following is true, the F-module detects a discrepancy error:

- The process value that does not represent the standard value is outside the configured tolerance window.
- Lasts longer than the configured discrepancy time.
- Lasts at maximum the duration of the maximum response time.

In the case of a discrepancy error, the F-module triggers a diagnostic interrupt and sets the process value to $7FFF_H$ for S7-300/400 F-CPUs or 0 for S7-1200/1500 F-CPUs. The discrepancy time is reset if the standard value lies within the tolerance window again.

In the PII, the substitute value 0 is set for the safety program.

You calculate the maximum discrepancy time that is permitted in the respective application using the following formula:

Discrepancy time = Maximum response time (in case of discrepancy error) – 2 × Conversion cycle time × Smoothing – 2 × Conversion cycle time

Note

You calculate the discrepancy time by using the values from section Discrepancy time (Page 69) in the above equation.

You can assign the discrepancy time for each channel pair.

"Standard value" parameter

You can select which of the two values is to be signaled to the F-CPU for each input channel pair. During a discrepancy between the two input channels, the last valid standard value prior to occurrence of the discrepancy is signaled to the F-CPU.

- "MIN": The lower of the two values is signaled to the F-CPU as the standard value.
- "MAX": The higher of the two values is signaled to the F-CPU as the standard value.

"Tolerance window %, absolute" parameter

You can calculate the absolute tolerance window using the following formula:

$$T_{abs} = \frac{|\Delta I_{abs}|}{I_{ME} - I_{MA}} \times 100 \ [\%]$$

Calculate the maximum deviation of the current using the following formula:

$$\Delta I_{abs} = \pm \frac{(I_{ME} - I_{MA}) \times T_{abs}}{100} \ [\text{mA}]$$

With

- I_{ME} = 20 mA (full-scale value)
- I_{MA} = 0 mA for measuring range 0 ... 20 mA (start-of-scale value)
- I_{MA} = 4 mA for measuring range 4 ... 20 mA (start-of-scale value)
- T_{abs} = Tolerance in %
- ΔI_{abs} = Maximum deviation of current (+/-)

You can assign a value of 2.0 to 20.0% for the "Tolerance window %, absolute" parameter for each channel pair.

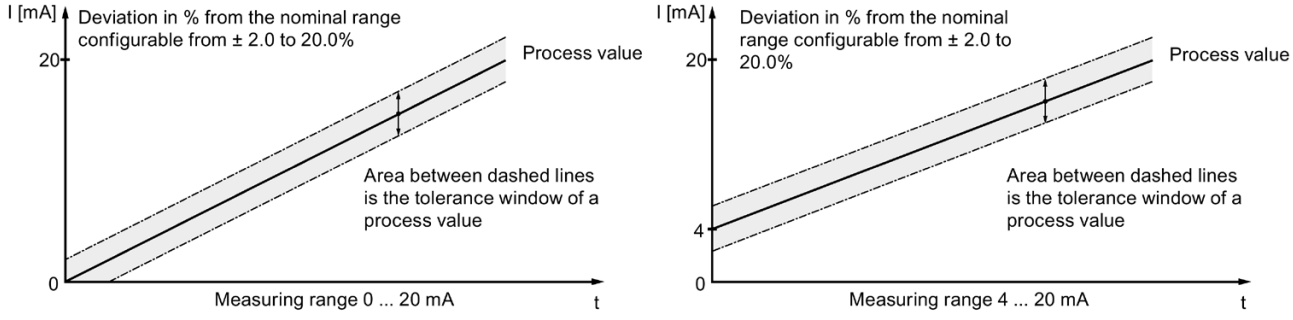


Figure 4-3 Absolute deviation in % of the nominal range for measuring range 0 to 20 mA or 4 to 20 mA

"Tolerance window %, relative" parameter

The tolerance window is calculated as a percentage of the **smoothed** process value that represents the MIN or MAX value (depending on the parameter assignment of the standard value) in this instant.

You can calculate the relative tolerance window using the following formula:

$$T_{rel} = \frac{\left| \Delta I_{rel} \right|}{\left| I_{EW} - I_{MA} \right|} \times 100 \ [\%]$$

Calculate the maximum deviation of the current using the following formula:

$$\Delta I_{rel} = \pm \frac{\left| I_{EW} - I_{MA} \right| \times T_{rel}}{100} \ [mA]$$

With

- I_{EW} = Process standard value (min./max.)
- I_{MA} = 0 mA for measuring range 0 ... 20 mA
- I_{MA} = 4 mA for measuring range 4 ... 20 mA
- T_{rel} = Tolerance in %
- ΔI_{rel} = Maximum deviation of current (+/-)

You can assign a value of 2.0 to 20.0% for the "Tolerance window %, relative" parameter for each channel pair.

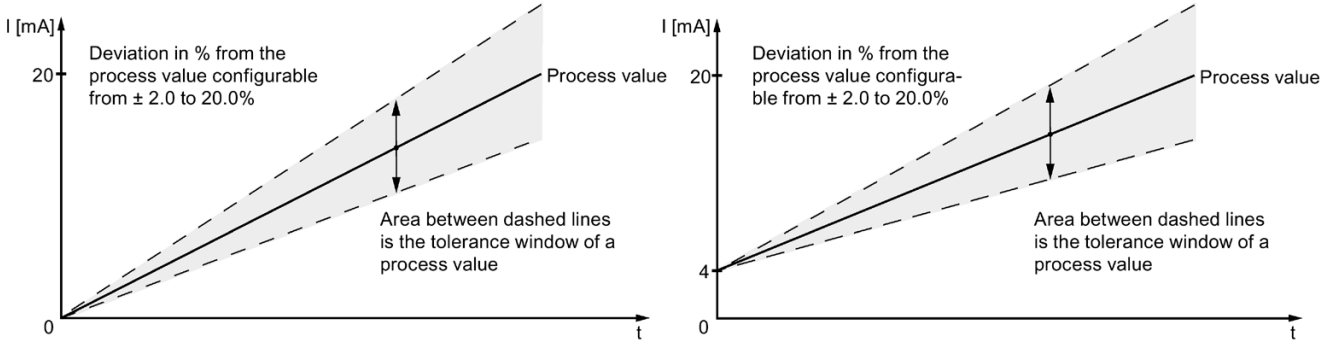


Figure 4-4 Relative deviation in % of the nominal range for measuring range 0 to 20 mA or 4 to 20 mA

Combination of the "Tolerance window %, absolute" and "Tolerance window %, relative" parameters

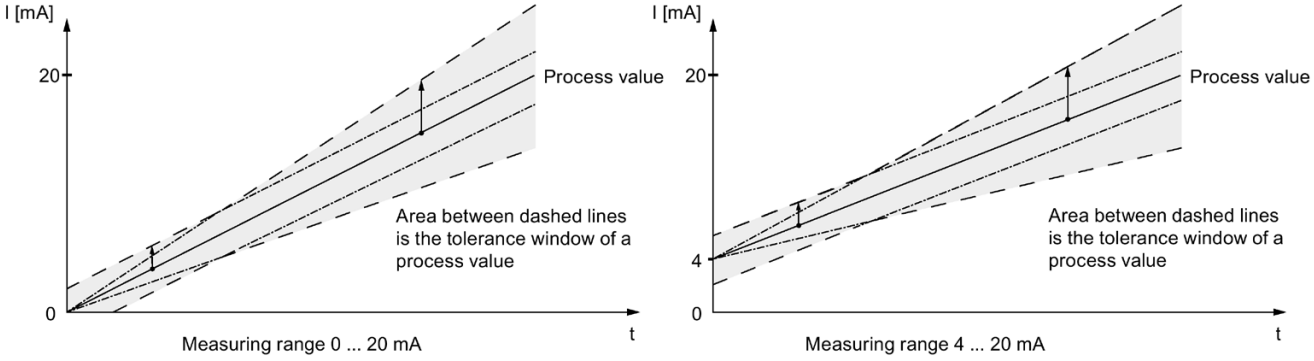
You can combine the "Tolerance window %, absolute" and "Tolerance window %, relative" parameters as needed. The combined tolerance window (shown in gray in the figure below) is the maximum of T_{rel} and T_{abs}.

$T = MAX \{ T_{rel}, T_{abs} \}$

$\Delta I = MAX \{ \Delta I_{rel}, \Delta I_{abs} \}$

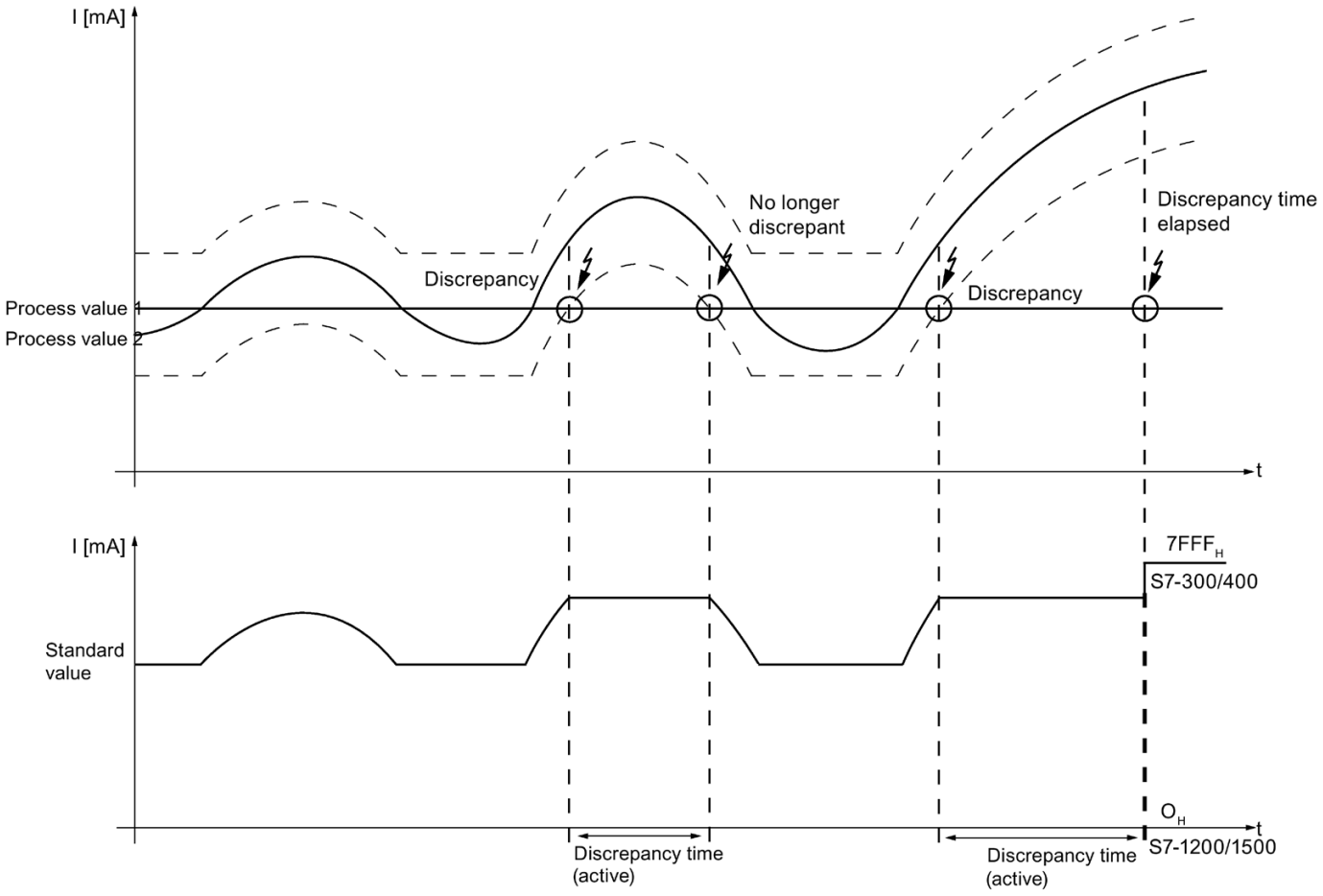
With

- T = Tolerance, in %
- ΔI = Maximum deviation of current (+/-)



Example

The following diagrams show you the behavior of the discrepancy evaluation when standard value = MAX.



The upper of the two diagrams shows you the characteristic curve of the two process values. The dashed line represents the absolute tolerance range configured in this example.

The lower of the two diagrams shows you the standard value signaled to the F-CPU.

In this example, on the first occurrence of a discrepancy, process value 1 is **within** the tolerance range again **before** expiration of the discrepancy time. This means the discrepancy error is not signaled.

In this example, on the second occurrence of a discrepancy, process value 1 is **outside** the tolerance range when the discrepancy time expires. As a result, a discrepancy error is signaled with $7FFF_H$ for S7-300/400 F-CPUs or 0 for S7-1200/1500 F-CPUs after expiration of the discrepancy time. In the PII, the substitute value 0 is set for the safety program.

See also

Discrepancy time (Page 24)

Tolerance window %, absolute (Page 25)

Tolerance window %, relative (Page 26)

4.3.2.8 Activated

If you select this check box, the corresponding channel is enabled for signal processing.

You can deactivate an unused channel with this parameter.

If you deactivate unused channels, the response time of the F-module is reduced.

4.3.2.9 Channel failure acknowledge

Use on S7-1200/1500 F-CPUs

The parameter is only relevant if the F-module can be operated on an S7-1200/1500 F-CPU.

The parameter can only be set if the F-parameter "Behavior after channel fault" is set to "Passivate channel" and the F-parameter "Reintegration after channel fault" is set to "Adjustable".

The value of this parameter specifies how the channel reacts after a channel fault:

- Manual: A channel failure is reintegrated after manual acknowledgment.
- Automatically: The channel is reintegrated automatically after a channel fault. Manual acknowledgment is not necessary.

Use in S7-300/400 F-CPUs

The value of this parameter is not relevant in the case of operation on S7-300/400 F-CPUs. For S7-300/400 F-CPUs you set the corresponding property at the F-I/O DB by means of the ACK_NEC tag.

For detailed information about the F-I/O DB, refer to the SIMATIC Safety – Configuring and Programming (http://support.automation.siemens.com/WW/view/en/54110126) manual.

4.3.2.10 Measuring range

You select the measuring range for the channel with this parameter:

- 0 to 20 mA
- 4 to 20 mA

4.3.2.11 Diagnostics: Wire break

Function

Here you activate wire break detection for a configured measuring range of 4 to 20 mA.

With an assigned measuring range of 4 to 20 mA:

- With assigned wire break diagnostics and currents < 3.6 mA, a wire break is detected and a diagnostic interrupt is triggered in the F-CPU.
- Without configured wire break and currents diagnostics < 0.4444 mA detects "underflow" and triggers a diagnostic interrupt in the F-CPU.

With an assigned measuring range of 0 to 20 mA, the wire break diagnostics is permanently set by default. With currents < 0.4442 mA, a wire break is detected and a diagnostic interrupt is triggered in the F-CPU.

If you do not need a channel, deactivate the channel. Then, a wire break is not detected.

4.3.2.12 Smoothing

Using smoothing

Smoothing of analog values provides a stabilized analog signal for further processing. Smoothed values are always used for discrepancy analysis.

WARNING
The smoothing takes place as a result of averaging over the selected number of most recently converted analog values of a channel, e.g. 64. The mean value generation causes a discrepancy to be delayed with a configured "1oo2 evaluation (max. SIL3/Cat.4/PLe)". You can find an example below.

Smoothing principle

The measured values are smoothed by a digital filter. Smoothing is achieved by the F-module forming the mean of a number of converted (digitized) analog values determined by the "Smoothing" parameter.

You assign smoothing in 7 levels (1, 2, 4, 8, 16, 32, 64 conversion cycles). The level determines the number of analog signals that are averaged. If smoothing = 1 is configured, the smoothing is deactivated.

A higher smoothing provides a more stable analog value, and prolongs the time it takes to apply a smoothed analog signal following a unit step. You can find an example below.

Note

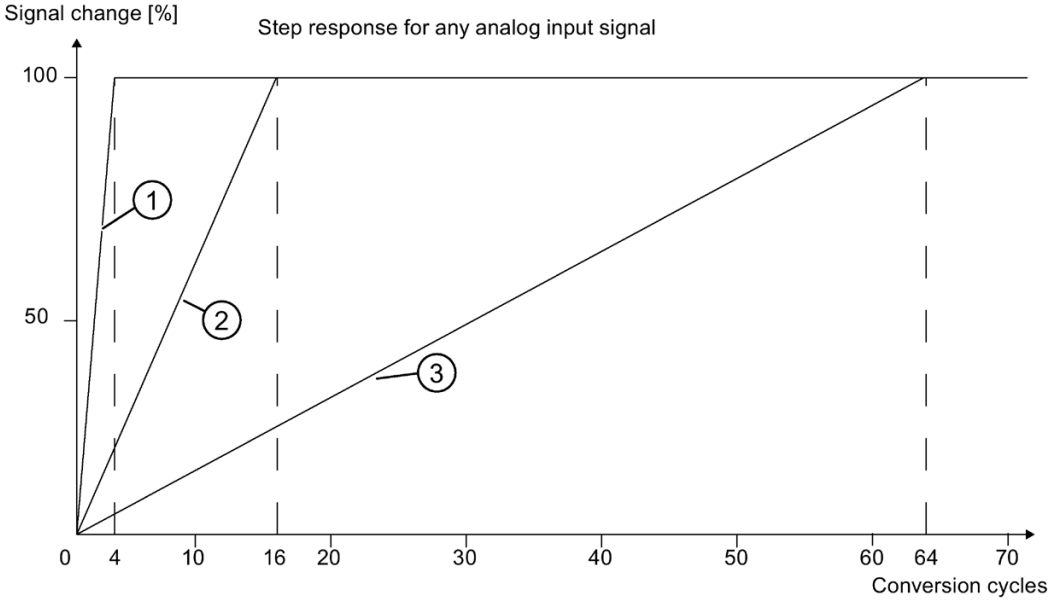
Smoothing is reset after startup, short circuit, wire break or another channel fault. If, for example, smoothing with 16 conversion cycles is assigned and all channels are active, it takes up to 2000 ms until the process value is signaled with a configured interference frequency suppression of 50 Hz.

Until the first valid process value, the F-module signals for the channel $7FFF_H$ for S7-300/400 F-CPUs or 0 for S7-1200/1500 F-CPUs.

If a discrepancy occurs, measuring and smoothing continues and is not restarted.

Example

The figure below shows the number of conversion cycles, depending on the smoothing setting, after which the analog value is completely smoothed and available in the case of a unit step. The figure applies to all signal changes at the analog input.



① Smoothing - 4 conversion cycles
② Smoothing - 16 conversion cycles
③ Smoothing - 64 conversion cycles

Example: Effect of smoothing on the maximum response time for a configured "1oo2 evaluation (max. SIL3/Cat.4/PLe)" in case of error

If an error (One Fault Delay Time, OFDT) occurred with a configured "1oo2 evaluation (max. SIL3/Cat.4/PLe)", you calculate the maximum response time according to the following formula:

Maximum response time (in case of discrepancy error) = 2 × Conversion cycle time × Smoothing + Discrepancy time + 2 × Conversion cycle time

Example: One channel pair connected and configured (activated), interference frequency 50 Hz, smoothing = 16 conversion cycles, discrepancy time = 2000 ms, conversion cycle time calculated with the formula from section Response times (Page 69):

Max. response time (in case of discrepancy error) = 2 × 70 ms × 16 + 2000 ms + 2 × 70 ms = 4380 ms

If a discrepancy exists between the two input channels, it can take 4380 ms until the F-module signals a discrepancy error to the F-CPU.

If the discrepancy time expires, an error is signaled and the process value is set to $7FFF_H$ for S7-300/400 F-CPUs or 0 for S7-1200/1500 F-CPUs. In the PII, the substitute value 0 is set for the safety program.

4.4 Address space

Address assignment for the analog input module F-AI 4xI 0(4)..20mA 2-/4-wire HF

The analog input module F-AI 4xI 0(4)..20mA 2-/4-wire HF occupies the following address areas in the F-CPU:

Table 4- 3 Address assignment in the F-CPU

Occupied bytes in the F-CPU:		
F-CPU	**In input range**	**In output range**
S7-300/400 F-CPUs	IB x + 0 to x + 12	QB x + 0 to x + 3
S7-1200/1500 F-CPUs	IB x + 0 to x + 13	QB x + 0 to x + 4

x = Module start address

Address assignment of the user data and the value status of the analog input module F-AI 4xI 0(4)..20mA 2-/4-wire HF

The user data occupy the following addresses in the analog input module F-AI 4xI 0(4)..20mA 2-/4-wire HF out of all the assigned addresses in the F-CPU:

Table 4- 4 User data address assignment in the input range

Byte in the F-CPU	Assigned bits in F-CPU per F-module:							
	7	**6**	**5**	**4**	**3**	**2**	**1**	**0**
IB x + 0	Input value at channel 0 (Result of the 1oo2 evaluation channel 0/2)							
IB x + 1								
IB x + 2	Input value at channel 1 (Result of the 1oo2 evaluation channel 1/3)							
IB x + 3								
IB x + 4	Input value at channel 2							
IB x + 5								
IB x + 6	Input value at channel 3							
IB x + 7								
IB x + 8	—	—	—	—	Value status* for AI_3	Value status* for AI_2	Value status* for AI_1	Value status* for AI_0

* Only S7-1200/1500 F-CPUs

x = Module start address

Note

You may only access the addresses occupied by user data and value status.

The other address areas occupied by the F-modules are assigned for functions including safety-related communication between the F-modules and F-CPU in accordance with PROFIsafe.

Additional information

For detailed information about F-I/O access, refer to the SIMATIC Safety – Configuring and Programming (http://support.automation.siemens.com/WW/view/en/54110126) manual.

Applications of the F-I/O module

5

You achieve SIL3/Cat.4/PLe with the following applications.

The wiring is performed on the suitable BaseUnit. Additional information is available in the Connecting section in the Distributed I/O System ET 200SP (http://support.automation.siemens.com/WW/view/en/58649293) System Manual.

5.1 Application 1: Safety mode SIL3/Cat.3/PLd with 2-wire transducer

Introduction

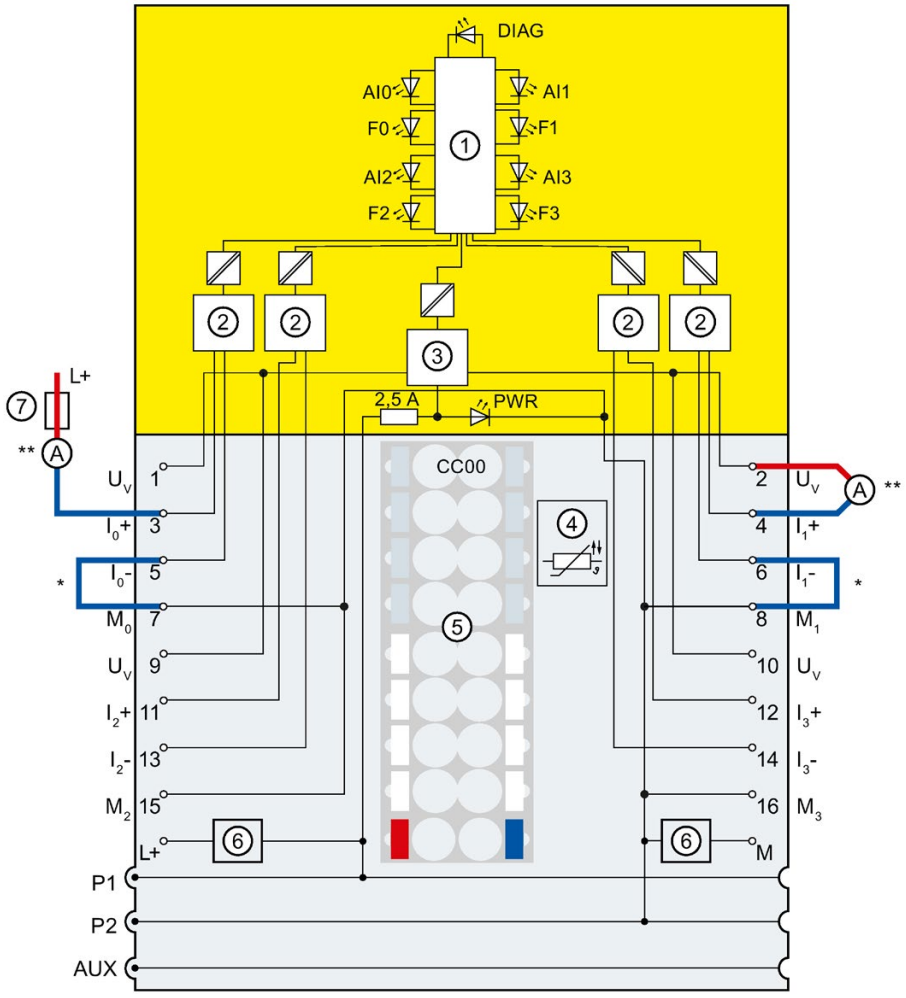
Below you will find the wiring scheme and the parameter assignment of the F-AI 4xI 0(4)..20mA 2-/4-wire HF for

- Application 1: Safety mode SIL3/Cat.3/PLd, 1oo1 (1v1) evaluation.

Possible diagnostic messages, the error causes and possible corrective measures are given in section "Diagnostic messages (Page 58)".

Current measurement 0/4 to 20 mA, 2-wire transducer

Four process signals can be connected to the F-module in this interconnection variant. Sensor supply U_V is provided by the F-module for 4 channels. You can also supply the sensors by means of an external sensor supply.



①	Backplane bus interface	U_V	Sensor supply
②	Analog-to-digital converter (ADC)	M	Supply voltage ground
③	Sensor supply/reverse polarity protection	M_n	Ground reference to U_V, channel n
④	Temperature measurement for BU type A1 only (the function cannot be used for this module.)	L+	24 V DC (infeed only with light-colored BaseUnit)
⑤	Color-coded label with color code CC00 (optional)	P1, P2, AUX	Internal self-assembling voltage buses Connection to left (dark-colored BaseUnit) Connection to left interrupted (light-colored BaseUnit)
⑥	Filter connection supply voltage (available with light-colored BaseUnit only)	DIAG	Diagnostics LED (green, red)
⑦	External fuse	AI0, AI1, AI2, AI3	Channel status LED (green)
I_n+	Current input positive, channel n	F0, F1, F2, F3	LED channel fault (red)
I_n-	Current input negative, channel n	PWR	Power LED (green)
*	Create the bridge directly at the terminal connection.	**	Measuring transducer

Figure 5-1 1oo1 evaluation

WARNING

To achieve SIL3/Cat.3/PLd using this wiring, you must use a suitably qualified sensor.

WARNING

All cables need to be laid in such a way that they are resistant to interference voltage. Use shielded cables.

Assignable parameters for application 1

Table 5- 1 Parameters for application 1 of F-AI 4xI 0(4)..20mA 2-/4-wire HF

Parameters	Range of values in safety mode
Behavior after channel faults	• Passivate the entire F-module • Passivate channel
Interference frequency suppression	• 50 Hz • 60 Hz
Sensor evaluation	1oo1 evaluation (max. SIL3/Cat.3/PLd)
Measuring range	• 0 ... 20 mA • 4 ... 20 mA
Diagnostics: Wire break	(in the measuring range 4 to 20 mA) • Disable • Enable
Smoothing	1 / 2 / 4 / 8 / 16 / 32 / 64 conversion cycles

5.2 Application 2: Safety mode SIL3/Cat.4/PLe with 2-wire transducer

Introduction

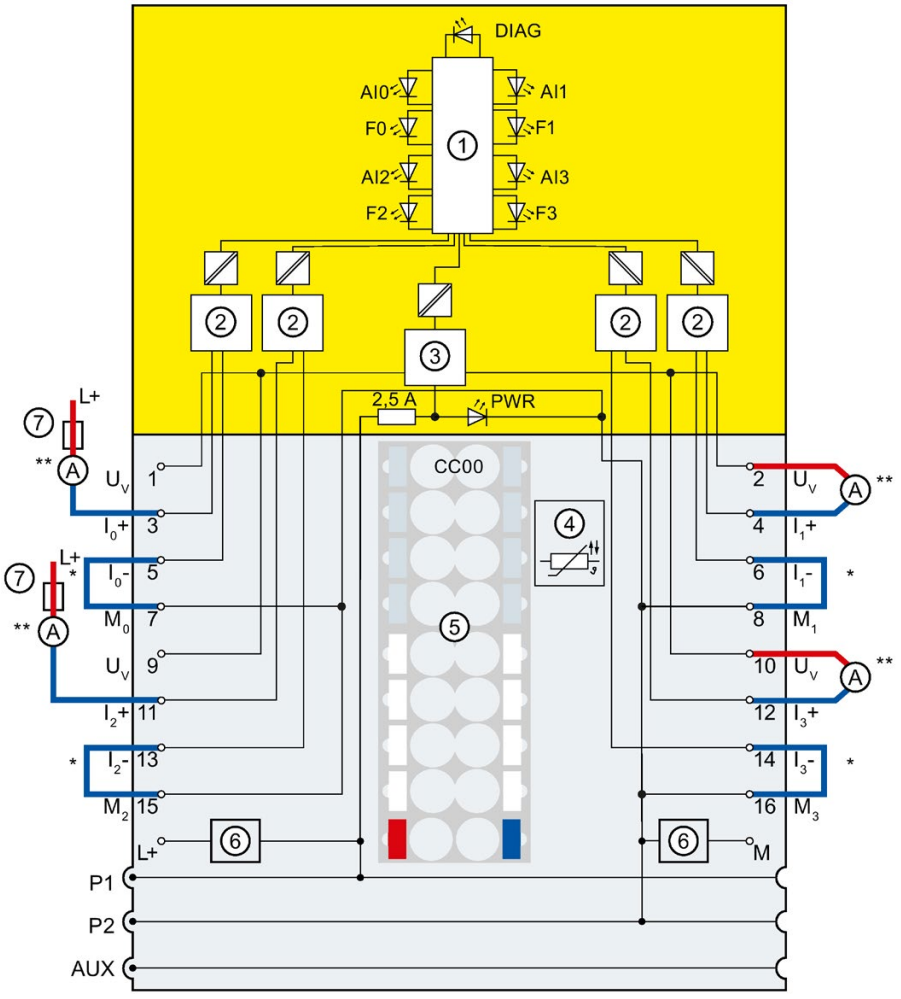
Below you will find the wiring scheme and the parameter assignment of the F-AI 4xI 0(4)..20mA 2-/4-wire HF for

- application 2: Safety mode SIL3/Cat.4/PLe, 1oo2 (2v2) evaluation.

Possible diagnostic messages, the error causes and possible corrective measures are given in section "Diagnostic messages (Page 58)".

Current measurement 0/4 to 20 mA, 2-wire transducer

Two process signals can be connected to the F-module in this interconnection variant. Sensor supply U_V is provided by the F-module for 4 channels. You can also supply the sensors by means of an external sensor supply.



①	Backplane bus interface	U_V	Sensor supply
②	Analog-to-digital converter (ADC)	M	Supply voltage ground
③	Sensor supply/reverse polarity protection	M_n	Ground reference to U_V, channel n
④	Temperature measurement for BU type A1 only (the function cannot be used for this module.)	L+	24 V DC (infeed only with light-colored BaseUnit)
⑤	Color-coded label with color code CC00 (optional)	P1, P2, AUX	Internal self-assembling voltage buses Connection to left (dark-colored BaseUnit) Connection to left interrupted (light-colored BaseUnit)
⑥	Filter connection supply voltage (available with light-colored BaseUnit only)	DIAG	Diagnostics LED (green, red)
⑦	External fuse	AI0, AI1, AI2, AI3	Channel status LED (green)
I_n+	Current input positive, channel n	F0, F1, F2, F3	LED channel fault (red)
I_n-	Current input negative, channel n	PWR	Power LED (green)
*	Create the bridge directly at the terminal connection.	**	Measuring transducer

Figure 5-2 1oo2 evaluation

WARNING

To achieve SIL3/Cat.4/PLe using this wiring, you must use a qualified, two-channel sensor or two qualified single-channel sensors.

WARNING

All cables need to be laid in such a way that they are resistant to interference voltage. Use shielded cables.

Assignable parameters for application 2

Table 5- 2 Parameters for application 2 of F-AI 4xI 0(4)..20mA 2-/4-wire HF

Parameters	Range of values in safety mode
Standard value	• MIN • MAX
Discrepancy time	100 to 30000 ms
Tolerance window %, absolute	2.0 to 20.0%
Tolerance window %, relative	2.0 to 20.0%
Behavior after channel faults	• Passivate the entire F-module • Passivate channel
Interference frequency suppression	• 50 Hz • 60 Hz
Sensor evaluation	1oo2 evaluation (max. SIL3/Cat.4/PLe)
Measuring range	• 0 to 20 mA • 4 to 20 mA
Diagnostics: Wire break	(in the measuring range 4 to 20 mA) • Disable • Enable
Smoothing	1 / 2 / 4 / 8 / 16 / 32 / 64 conversion cycles

5.3 Application 3: Safety mode SIL3/Cat.3/PLd with 4-wire transducer

Introduction

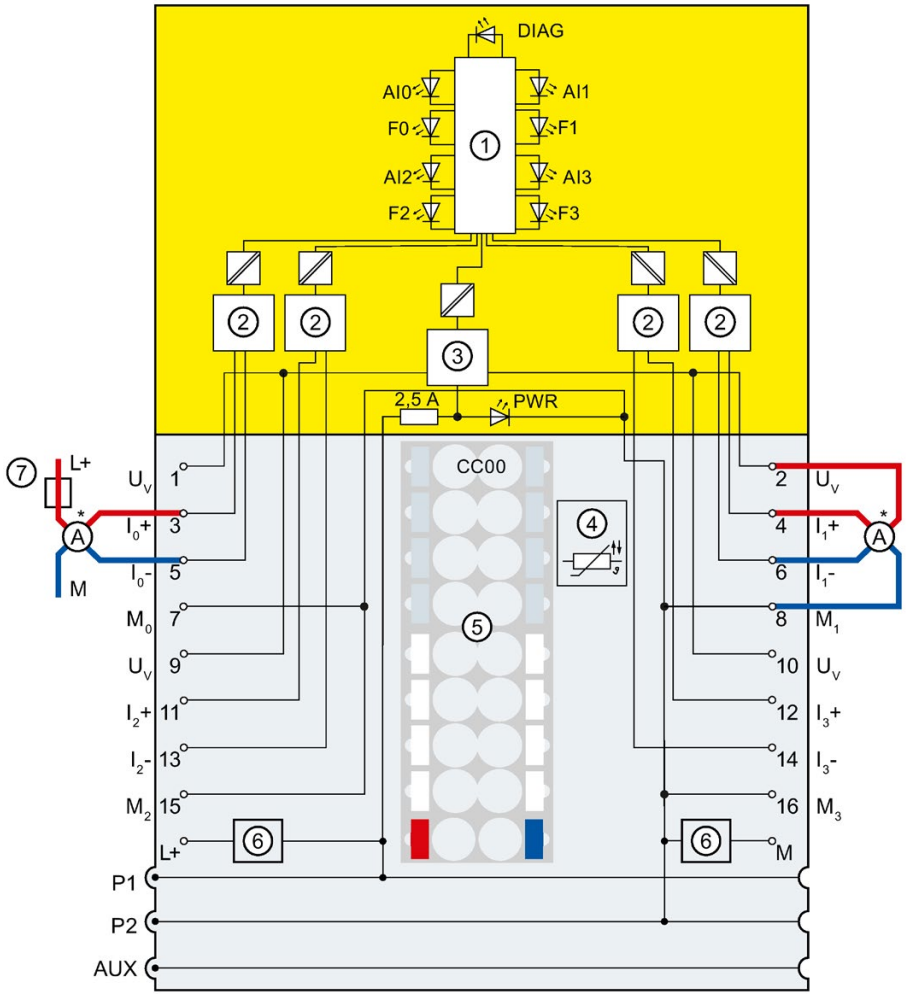
Below you will find the wiring scheme and the parameter assignment of the F-AI 4xI 0(4)..20mA 2-/4-wire HF for

- Application 3: Safety mode SIL3/Cat.3/PLd, 1oo1 (1v1) evaluation.

Possible diagnostic messages, the error causes and possible corrective measures are given in section "Diagnostic messages (Page 58)".

Current measurement 0/4 to 20 mA, 4-wire transducer

Four process signals can be connected to the F-module in this interconnection variant. Sensor supply U_V is provided by the F-module for 4 channels. You can also supply the sensors by means of an external sensor supply.



①	Backplane bus interface	U_V	Sensor supply
②	Analog-to-digital converter (ADC)	M	Supply voltage ground
③	Sensor supply/reverse polarity protection	M_n	Ground reference to U_V, channel n
④	Temperature measurement for BU type A1 only (the function cannot be used for this module.)	L+	24 V DC (infeed only with light-colored BaseUnit)
⑤	Color-coded label with color code CC00 (optional)	P1, P2, AUX	Internal self-assembling voltage buses Connection to left (dark-colored BaseUnit) Connection to left interrupted (light-colored BaseUnit)
⑥	Filter connection supply voltage (available with light-colored BaseUnit only)	DIAG	Diagnostics LED (green, red)
⑦	External fuse	AI0, AI1, AI2, AI3	Channel status LED (green)
I_n+	Current input positive, channel n	F0, F1, F2, F3	LED channel fault (red)
I_n-	Current input negative, channel n	PWR	Power LED (green)
*	Measuring transducer		

Figure 5-3 1oo1 evaluation

WARNING

To achieve SIL3/Cat.3/PLd using this wiring, you must use a suitably qualified sensor.

WARNING

All cables need to be laid in such a way that they are resistant to interference voltage. Use shielded cables.

Assignable parameters for application 3

Table 5- 3 Parameters for application 3 of F-AI 4xI 0(4)..20mA 2-/4-wire HF

Parameters	Range of values in safety mode
Behavior after channel faults	• Passivate the entire F-module • Passivate channel
Interference frequency suppression	• 50 Hz • 60 Hz
Sensor evaluation	1oo1 evaluation (max. SIL3/Cat.3/PLd)
Measuring range	• 0 to 20 mA • 4 to 20 mA
Diagnostics: Wire break	(in the measuring range 4 to 20 mA) • Disable • Enable
Smoothing	1 / 2 / 4 / 8 / 16 / 32 / 64 conversion cycles

5.4 Application 4: Safety mode SIL3/Cat.4/PLe with 4-wire transducer

Introduction

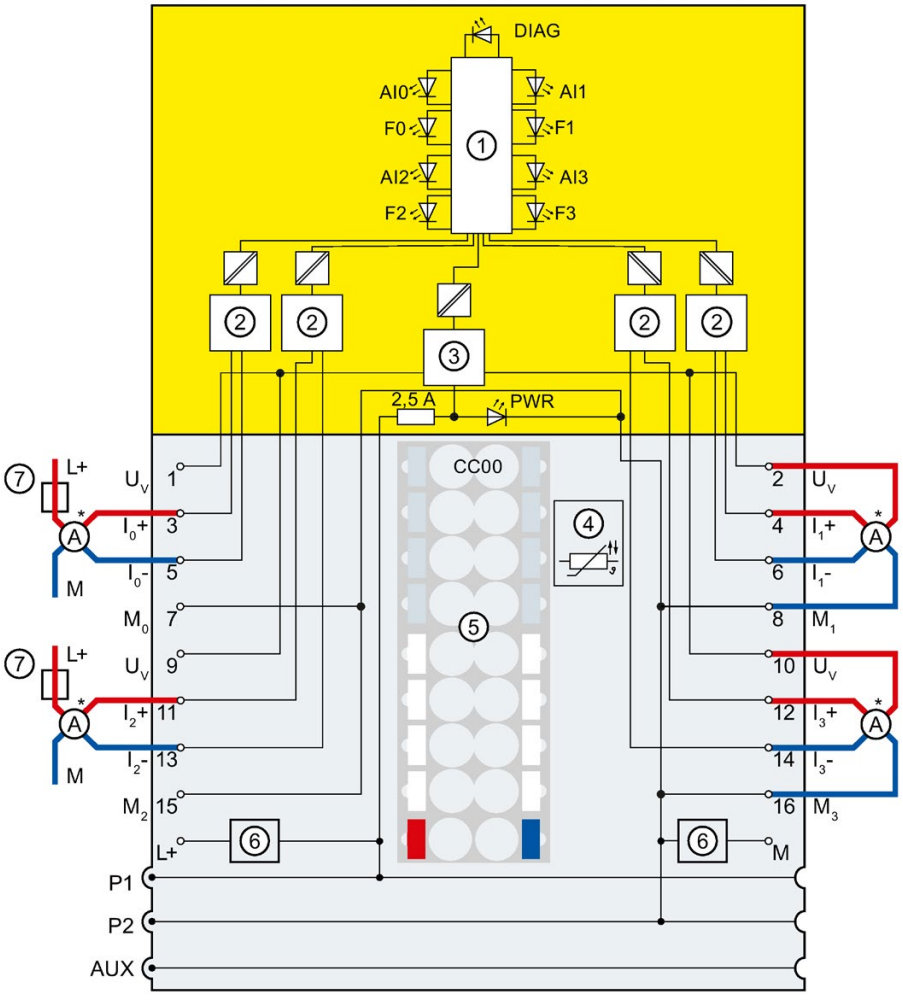
Below you will find the wiring scheme and the parameter assignment of the F-AI 4xI 0(4)..20mA 2-/4-wire for

- application 4: Safety mode SIL3/Cat.4/PLe, 1oo2 (2v2) evaluation.

Possible diagnostic messages, the error causes and possible corrective measures are given in section "Diagnostic messages (Page 58)".

Current measurement 0/4 to 20 mA, 4-wire transducer

Two process signals can be connected to the F-module in this interconnection variant. Sensor supply U_V is provided by the F-module for 4 channels. You can also supply the sensors by means of an external sensor supply.



①	Backplane bus interface	U_V	Sensor supply
②	Analog-to-digital converter (ADC)	M	Supply voltage ground
③	Sensor supply/reverse polarity protection	M_n	Ground reference to U_V, channel n
④	Temperature measurement for BU type A1 only (the function cannot be used for this module.)	L+	24 V DC (infeed only with light-colored BaseUnit)
⑤	Color-coded label with color code CC00 (optional)	P1, P2, AUX	Internal self-assembling voltage buses Connection to left (dark-colored BaseUnit) Connection to left interrupted (light-colored BaseUnit)
⑥	Filter connection supply voltage (available with light-colored BaseUnit only)	DIAG	Diagnostics LED (green, red)
⑦	External fuse	AI0, AI1, AI2, AI3	Channel status LED (green)
I_n+	Current input positive, channel n	F0, F1, F2, F3	LED channel fault (red)
I_n-	Current input negative, channel n	PWR	Power LED (green)
*	Measuring transducer		

Figure 5-4 1oo2 evaluation

WARNING

To achieve SIL3/Cat.4/PLe using this wiring, you must use suitably qualified sensors.

WARNING

All cables need to be laid in such a way that they are resistant to interference voltage. Use shielded cables.

Assignable parameters for application 4

Table 5- 4 Parameters for application 4 of F-AI 4xI 0(4)..20mA 2-/4-wire HF

Parameters	Range of values in safety mode
Standard value	• MIN • MAX
Discrepancy time	100 to 30000 ms
Tolerance window %, absolute	2.0 to 20.0%
Tolerance window %, relative	2.0 to 20.0%
Behavior after channel faults	• Passivate the entire F-module • Passivate channel
Interference frequency suppression	• 50 Hz • 60 Hz
Sensor evaluation	1oo2 evaluation (max. SIL3/Cat.4/PLe)
Measuring range	• 0 to 20 mA • 4 to 20 mA
Diagnostics: Wire break	(in the measuring range 4 to 20 mA) • Disable • Enable
Smoothing	1 / 2 / 4 / 8 / 16 / 32 / 64 conversion cycles

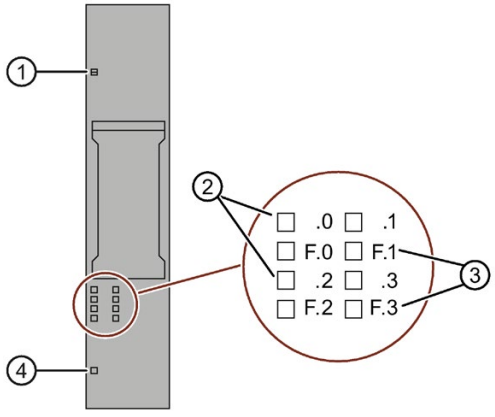
Interrupts/diagnostic messages

6

6.1 Status and error display

LED display

The following figure shows the LED display of the F-AI 4xI 0(4)..20mA 2-/4-wire HF.



① DIAG (green/red)
② Channel status (green)
③ Channel fault (red)
④ PWR (green)

Figure 6-1 LED display

Meaning of the LED displays

The following tables show the meaning of the status and error displays. Remedies for diagnostics alarms can be found in section Diagnostic messages (Page 58).

WARNING
The DIAG LED and the channel status and channel fault LEDs of the outputs are not designed as safety-related LEDs and therefore may not be evaluated for safety-related activities.

DIAG LED

Table 6- 1 Error display of the LED DIAG

DIAG	Meaning
Off	Backplane bus supply of the ET 200SP not okay
Flashing	Module parameters not configured
On	Module parameters configured and no module diagnostics
Flashing	• Module parameters configured and module diagnostics • Operation in S7-1200/1500 F-CPUs: At least one channel is waiting for a user acknowledgment.
Flashing	• Operation in S7-1200/1500 F-CPUs: The F-module is waiting for a user acknowledgment after a module fault. • Operation in S7-300/400 F-CPUs: The F-module is waiting for a user acknowledgment.

Channel status/channel fault LED

Table 6- 2 Status display of the LEDs channel status / channel error

Channel status	Channel fault	Meaning
Off	Off	Channel deactivated or supply voltage L+ missing.
On	Off	Channel activated and no channel diagnostics
Off	On	Channel activated and channel diagnostics
/ Alternately flashing		At least one channel is waiting for a user acknowledgment.

Channel status/DIAG/channel fault LED

Table 6- 3 Status display of the LEDs channel status / DIAG / channel error

Channel status	DIAG	Channel fault	Meaning
Off	Flashing	All On	The PROFIsafe address does not match the configured PROFIsafe address.
Flashing	Flashing	Off	Identification of the F-module when assigning the PROFIsafe address.

PWR LED

Table 6- 4 Status display of LED PWR

PWR	Meaning
Off	Supply voltage L+ missing
On	Supply voltage L+ available

6.2 Interrupts

Introduction

The fail-safe analog input module F-AI 4xI 0(4)..20mA 2-/4-wire HF supports diagnostic interrupts.

Diagnostic interrupt

The F-module generates a diagnostic interrupt for each diagnostic message described in section Diagnostic messages (Page 58).

The list below provides an overview of the diagnostic interrupts of the F-module. The diagnostic interrupts are assigned either to one channel or the entire F-module.

⚠ WARNING

Before acknowledging the short circuit diagnostic message, remedy the respective fault and validate your safety function. Follow the fault remedying procedure described in section Diagnostic messages (Page 58)

Scope of diagnostic interrupt: F-module

- Overtemperature
- Parameter error
- Supply voltage missing
- Channel/component temporarily not available
- Mismatch of safety destination address (F_Dest_Add)
- Safety destination address not valid (F_Dest_Add)
- Safety source address not valid (F_Source_Add)
- Safety watchdog timer value is 0 ms (F_WD_Time)
- Parameter F_SIL exceeds SIL from specific device application
- Parameter F_CRC_Length does not match the generated values
- Version of F-parameter set incorrectly
- CRC1 fault
- Inconsistent iParameters (iParCRC error)
- F_Block_ID not supported
- Transmission error: Inconsistent data (CRC error)
- Transmission error: Timeout (monitoring time 1 or 2 expired)
- Module is defective
- Watchdog tripped
- Invalid/inconsistent firmware present

- Diagnostics memory overflow
- Channel failure acknowledgment
- F-address memory not accessible
- No valid F-address available
- Diagnostics memory overflow
- Undertemperature
- Supply voltage too high
- Supply voltage too low
- Channel/component not available

Scope of diagnostic interrupt: Channel

- Diagnostics: Wire break (can only be configured for measuring range 4..20mA)
- High limit exceeded
- Low limit violated
- Safety-related switch off
- Internal supply voltage of the module failed
- Common mode error
- Analog input signal not recorded unique
- Internal sensor supply short-circuit to P
- Overload or internal sensor supply short-circuit to M
- Discrepancy error
- Analog input signal not recorded unique
- Internal sensor supply short-circuit to P
- Overload or internal sensor supply short-circuit to M
- Read back failure
- ADC error
- Fault in test circuit

6.3 Diagnostic messages

Diagnostic messages

Module faults are indicated as diagnostics (module status).

Once the fault is eliminated, the F-module must be reintegrated in the safety program. For additional information on passivation and reintegration of F-I/O, refer to the SIMATIC Safety – Configuring and Programming (http://support.automation.siemens.com/WW/view/en/54110126) manual.

Table 6- 5 Diagnostic messages of the F-AI 4xI 0(4)..20mA 2-/4-wire HF

Diagnostic message	Fault code	Meaning	Remedy
Overtemperature	5_H	The F-module measured an excessively high temperature.	Operate the F-module within the specified temperature range (see Technical specifications (Page 64)) Once the temperature has been reduced and returns to the specified range, the F-module must be removed and inserted or the power switched OFF and ON.
Wire break	6_H	Possible causes: • A cable to the sensor is broken. • Fault at the external circuit • Defective sensor • Wrong sensor type set in the parameters • Input channel not used • Measurement resistance too high	Check the possible causes and eliminate the fault.
High limit exceeded	7_H	The measured value exceeds the measuring range.	Check the interaction between the module and the sensor.
Low limit violated	8_H	The measured input value is below a measuring range.	Check the interaction between the module and the sensor.
Parameter error	10_H	Parameter assignment errors include: • The F-module cannot use the parameters (unknown, invalid combination, etc.). • The F-module parameters have not been configured.	Correct the parameter assignment.
Supply voltage missing	11_H	Missing or insufficient supply voltage L+	• Check the supply voltage L+ on the BaseUnit. • Check the BaseUnit.

Diagnostic message	Fault code	Meaning	Remedy
Safety-related switch off	19_H	For safety purposes, channel was switched off due to an error on another channel. Possible causes: • Short circuit is present.	• Correct the process wiring.
Channel/component temporarily not available	$1F_H$	Possible causes: • Internal fault in the F-module • Firmware update error	• Replace the F-module. • Repeat the firmware update.
Mismatch of safety destination address (F_Dest_Add)	40_H	The F-module detected a different F-destination address.	• Check the parameter assignment of the PROFIsafe driver and the PROFIsafe address assigned to the F-module. • Assign the PROFIsafe address to the F-module (again).
Safety destination address not valid (F_Dest_Add)	41_H	The F-module detected an invalid F-destination address.	
Safety source address not valid (F_Source_Add)	42_H	The F-module detected a different F-source address.	
Safety watchdog timer value is 0 ms (F_WD_Time)	43_H	The F-module detected an invalid safety watchdog time.	
Parameter F_SIL exceeds SIL from specific device application	44_H	The F-module detected a discrepancy between the SIL setting of the communication and the application.	
Parameter F_CRC_Length does not match the generated values	45_H	The F-module detected a discrepancy in the CRC length.	
Version of F-parameter set incorrectly	46_H	The F-module detected an incorrect F_Par_Version or an invalid F_Block_ID.	
CRC1 fault	47_H	The F-module detected inconsistent F-parameters.	
Transmission error: Inconsistent data (CRC error)	$4D_H$	The F-module detected a CRC error. Possible causes: • The communication between the F-CPU and F-module is disturbed. • Electromagnetic interference has exceeded limits. • An error occurred in the sign-of-life monitoring.	• Check the communication connection between the F-module and F-CPU. • Eliminate the electromagnetic interference.
Inconsistent iParameters (iParCRC error)	51_H	The firmware of the F-module has detected inconsistent iParameters.	Check the parameter assignment.
F_Block_ID not supported	52_H	The F-module detected an incorrect block ID.	Check the parameter assignment of the PROFIsafe driver.
Transmission error: Timeout (monitoring time 1 or 2 expired)	54_H	The F-module detected a timeout. Possible causes: • The F-monitoring time is set incorrectly. • A bus fault is present.	• Check the parameter assignment. • Ensure that communication is functioning correctly.

Diagnostic message	Fault code	Meaning	Remedy
Module is defective	100_H	Possible causes: • Electromagnetic interference has exceeded limits. • The F-module has detected an internal error and has reacted in a safety-related manner.	• Eliminate the interference. The module must then be pulled and plugged, or the power switched OFF and ON. • If the F-module cannot be put back into operation, consider replacing it.
Watchdog tripped	103_H	Possible causes: • Electromagnetic interference has exceeded limits. • The F-module has detected an internal error and has reacted in a safety-related manner.	• Eliminate the interference. The module must then be pulled and plugged, or the power switched OFF and ON. • If the F-module cannot be put back into operation, consider replacing it.
Internal supply voltage of the module failed	104_H	Internal voltage is too low.	Replace the F-module.
Common mode error	118_H	Voltage between two input channels is too high.	Correct the input wiring.
Invalid/inconsistent firmware present	$11B_H$	The firmware is incomplete and/or firmware added to the F-module is incompatible. This leads to errors or functional limitations when operating the F-module.	• Perform a firmware update for the F-module. Note any error messages. • Use only firmware versions released for this F-module.
Diagnostics memory overflow	$13E_H$	Overflow of the diagnostics memory. It was not possible to send all pending diagnostics. This error can lead to deactivation of the F-module and even to switch off/on of the supply voltage.	Remedy the cause of the diagnostics surge.
Analog input signal not recorded unique	304_H	Measured values from the sensor are not plausible. Possible causes: • Increased EMC • F-module defective	Check the interaction between the F-module and the sensor.
Internal sensor supply short-circuit to P	306_H	Possible causes: • Short-circuit of internal sensor supply to P	Check the process wiring.
Overload or internal sensor supply short-circuit to M	307_H	• The internal sensor supply is overloaded. • Missing or insufficient supply voltage L+.	• Eliminate the short-circuit in the process wiring. • Check the supply voltage L+ on the BaseUnit. • Check the BaseUnit.

Diagnostic message	Fault code	Meaning	Remedy
Channel failure acknowledgment	$30B_H$	A channel fault was detected. Confirmation is required to enable the channel.	Confirm the channel fault.
No valid F-address available	$30D_H$	The F-source address and F-destination address stored in the electronic coding element cannot be accessed.	Verify that the coding element is present. Replace the coding element, if necessary.
F-address memory not accessible	$30E_H$	No valid PROFIsafe address is saved in the retentive memory. Possible causes: • Initial commissioning • Deliberate parameter change of the PROFIsafe address • Deviation between target and actual configuration of the plant.	• In the case of initial commissioning or deliberate parameter change, assign the PROFIsafe address. • Check the consistency of the target and actual configuration.
Undertemperature	312_H	The minimum permissible temperature limit has been violated.	Operate the F-module within the specified temperature range (see Technical specifications (Page 64))
Discrepancy error	314_H	The discrepancy time set for 1oo2 operation has been exceeded. Possible causes of the discrepancy error: • Incorrect parameter assignment • Wire break in the sensor's supply cable	Check the discrepancy time, the sensors and the cabling.
Read back failure	$31E_H$	The F-module detected an internal error in the test connection. Possible causes: • Increased EMC • F-module defective	If the error persists, replace the F-module.
Auxiliary voltage too high	321_H	The supply voltage is too high.	Check the supply voltage and then test the safety application.
Auxiliary voltage too low	322_H	The supply voltage is too low.	Check the supply voltage and then test the safety application.
ADC error	331_H	Internal error during analog-digital conversion. Possible causes: • Increased EMC • F-module defective	If the error persists, replace the F-module.
Fault in test connection	332_H	The F-module detected an internal error in the test connection. Possible causes: • Increased EMC • F-module defective	If the error persists, replace the F-module.

Supply voltage outside the nominal range

If the supply voltage L+ is outside the specified value range, the DIAG LED flashes and the module is passivated.

When the voltage is then recovered (level must remain within the specified value for at least 1 minute (see Technical specifications (Page 64): Voltages, Currents, Potentials)), the DIAG LED stops flashing. The module remains passivated.

Generally applicable information on diagnostics

Information on diagnostics that pertains to all fail-safe modules (for example, readout of diagnostics functions or passivation of channels) is available in the SIMATIC Safety – Configuring and Programming (http://support.automation.siemens.com/WW/view/en/54110126) manual.

6.4 Value status

Properties

In addition to the diagnostic messages and the status and fault display, the F-module provides information about the validity of each analog input signal – the value status. The value status is entered in the process image along with the input signal.

Value status for digital input and output modules

The value status is the binary additional information of an analog input signal. The value status is entered in the process image of the inputs (PII) at the same time as the process signal. It provides information about the validity of the analog input signal.

The value status is affected by all faults.

- 1_B: A valid process value is output for the channel.
- 0_B: A fail-safe value is output for the channel, or the channel is deactivated.

Note

You may only access the addresses occupied by user data and value status.

The other address areas occupied by the F-modules are assigned for functions including safety-related communication between the F-modules and F-CPU in accordance with PROFIsafe.

1oo2 evaluation of the sensors combines the two channels. With 1oo2 evaluation of the sensors, you can only access the low order channel in the safety program, e.g. channel 0.

Assignment of the inputs and value status in the PII

Each channel of the F-module is assigned a value status in the process image of the inputs. You can find the assignment in section Address space (Page 38).

Reference

A detailed description of the evaluation and processing of the respective input signals can be found in the SIMATIC Safety – Configuring and Programming (http://support.automation.siemens.com/WW/view/en/54110126) manual.

Technical specifications

7

7.1 Technical specifications

Technical specifications of the F-AI 4xI 0(4)..20mA 2-/4-wire HF

Article number	6ES7136-6AA00-0CA1
General information	
Product type designation	F-AI 4xI 0(4) ... 20 mA 2/4-wire HF
Firmware version	
• FW update possible	Yes
usable BaseUnits	BU type A0, A1
Color code for module-specific color identification plate	CC00
Product function	
• I&M data	Yes; I&M0 to I&M3
Engineering with	
• STEP 7 TIA Portal configurable/integrated as of version	V15 with HSP 203
CiR – Configuration in RUN	
Reparameterization possible in RUN	No
Calibration possible in RUN	No
Supply voltage	
Rated value (DC)	24 V
permissible range, lower limit (DC)	19.2 V
permissible range, upper limit (DC)	28.8 V
Reverse polarity protection	Yes
Input current	
Current consumption (rated value)	0.38 A
Current consumption, max.	0.4 A
24 V encoder supply	
• 24 V	Yes; min. L+ (-1.5 V)
• Short-circuit protection	Yes
• Output current, max.	300 mA; total current of all encoders/ channels
Power	
Power available from the backplane bus	70 mW
Power loss	
Power loss, typ.	2 W

Article number	6ES7136-6AA00-0CA1
Address area	
Address space per module	
• Inputs	14 byte; S7-300/400F CPU, 13 byte
• Outputs	5 byte; S7-300/400F CPU, 4 byte
Hardware configuration	
Automatic encoding	
• Electronic coding element type F	Yes
Analog inputs	
Number of analog inputs	4
• For current measurement	4
permissible input current for current input (destruction limit), max.	35 mA
Input ranges (rated values), currents	
• 0 to 20 mA	Yes
• Input resistance (0 to 20 mA)	125 Ω
• 4 mA to 20 mA	Yes
• Input resistance (4 mA to 20 mA)	125 Ω
Cable length	
• shielded, max.	1 000 m
Analog value generation for the inputs	
Measurement principle	Sigma Delta
Integration and conversion time/resolution per channel	
• Resolution with overrange (bit including sign), max.	16 bit
• Integration time, parameterizable	Yes
• Integration time (ms)	20 / 16,667
• Interference voltage suppression for interference frequency f1 in Hz	50 / 60 Hz
Smoothing of measured values	
• Number of smoothing levels	7
• parameterizable	Yes
• Step: None	Yes; 1x conversion cycle time
• Step: low	Yes; 2x / 4x conversion cycle time
• Step: Medium	Yes; 8x / 16x conversion cycle time
• Step: High	Yes; 32x / 64x conversion cycle time

Article number	6ES7136-6AA00-0CA1
Encoder	
Connection of signal encoders	
• for current measurement as 2-wire transducer	Yes
– Burden of 2-wire transmitter, max.	650 Ω
• for current measurement as 4-wire transducer	Yes
Errors/accuracies	
Linearity error (relative to input range), (+/-)	0.1 %
Temperature error (relative to input range), (+/-)	0.023 %/K
Repeat accuracy in steady state at 25 °C (relative to input range), (+/-)	0.1 %
Operational error limit in overall temperature range	
• Current, relative to input range, (+/-)	2 %
Basic error limit (operational limit at 25 °C)	
• Current, relative to input range, (+/-)	0.1 %
Interference voltage suppression for f = n x (f1 +/- 1 %), f1 = interference frequency	
• Series mode interference (peak value of interference < rated value of input range), min.	40 dB
• Common mode interference, min.	70 dB
Interrupts/diagnostics/status information	
Diagnostics function	Yes, "Alarms/diagnostic messages" section in the manual
Alarms	
• Diagnostic alarm	Yes
• Limit value alarm	Yes
Diagnostic messages	
• Monitoring the supply voltage	Yes
• Wire-break	Yes; Measuring range 4 to 20 mA only
• Short-circuit	Yes
Diagnostics indication LED	
• RUN LED	Yes; Green LED
• ERROR LED	Yes; Red LED
• Monitoring of the supply voltage (PWR-LED)	Yes; green PWR LED
• Channel status display	Yes; Green LED
• for channel diagnostics	Yes; Red LED
• for module diagnostics	Yes; Green/red LED

Article number	6ES7136-6AA00-0CA1
Potential separation	
Potential separation channels	
• between the channels	No
• between the channels and backplane bus	Yes
• between the channels and the power supply of the electronics	Yes
Permissible potential difference	
between the inputs (UCM)	10 Vpp
Isolation	
Isolation tested with	707 V DC (type test)
Standards, approvals, certificates	
Highest safety class achievable in safety mode	
• Performance level according to ISO 13849-1	PLe
• Category according to ISO 13849-1	Cat. 4
• SIL acc. to IEC 61508	SIL 3
Probability of failure (for service life of 20 years and repair time of 100 hours)	
– Low demand mode: PFDavg in accordance with SIL3	< 5.00E-05
– High demand/continuous mode: PFH in accordance with SIL3	< 1.00E-09 1/h
Ambient conditions	
Ambient temperature during operation	
• horizontal installation, min.	0 °C
• horizontal installation, max.	60 °C
• vertical installation, min.	0 °C
• vertical installation, max.	50 °C
Dimensions	
Width	15 mm
Weights	
Weight, approx.	48 g

Operational limit in complete temperature range

WARNING

When designing the safety function, you must take into account the information "Operational limit in complete temperature range" for the entire mission time.

Temperature characteristic values

Note

When the ambient temperature exceeds 55 °C, you must only apply a maximum total current of 3 A to an adjacent F-DQ 4x24VDC/2A PM HF.

Dimension drawing

See ET 200SP BaseUnits manual

See also

ET 200SP BaseUnits
(http://support.automation.siemens.com/WW/view/en/58532597/133300)

Response times

A

Introduction

You will find the response times of the F-AI 4xI 0(4)..20mA 2-/4-wire HF below. The response times are included in the calculation of the F-system response time.

Definition of response time for fail-safe analog inputs

The response time results from the number of channels/channel pairs, the response time per channel/channel pair, the basic response time and the configured smoothing.

Times required for the calculation

- Max. acknowledgment time (Device Acknowledgment Time): T_{DAT} = 20 ms
- Basic response time: 20 ms
- Response time per channel
  - At 50 Hz: 25 ms
  - At 60 Hz: 22 ms

Conversion cycle time = basic response time + (N × response time per channel)

(N = number of active channels)

The conversion cycle time is the time in which all activated channels are processed/converted once.

Typical response time

You can calculate the typical response time of F-AI 4xI 0(4)..20mA 2-/4-wire HF using the following formula:

Typical response time = Conversion cycle time × Smoothing

Max. response time (worst case delay time, WCDT)

You can calculate the maximum response time of F-AI 4xI 0(4)..20mA 2-/4-wire HF (worst case delay time, WCDT) using the following formula:

Max. response time = 2 × Conversion cycle time × Smoothing

Response time in the case of a fault (one fault delay time, OFDT)

You can calculate the response time of F-AI 4xI 0(4)..20mA 2-/4-wire HF (one fault delay time, OFDT) as follows:

- According to the following formula if a discrepancy error is present:

  Typical response time = Conversion cycle time × Smoothing + Discrepancy time + Conversion cycle time

  Maximum response time = 2 × Conversion cycle time × Smoothing + Discrepancy time + 2 × Conversion cycle time

- According to the following formula if a channel fault is present:

  Typical response time = Conversion cycle time

  Max. response time = 2 × Conversion cycle time

This means that, for OFDT, the time on occurrence of a discrepancy error should be taken with parameter assignment "1oo2 evaluation (max. SIL3/Kat.4/PLe)" and the time on occurrence of a channel fault should be taken with parameter assignment "1oo1 evaluation (max. SIL3/Kat.3/PLd)".

Representation of analog values

B

In this section we are presenting the analog values for all measuring ranges that you can use with the F-AI 4xI 0(4)..20mA 2-/4-wire HF analog input module.

Measured value resolution

The analog values are shown as fixed-point number in two's complement.

The resolutions shown here are 16 bits including sign.

Table B- 1 Resolution of the analog values

Resolution in bits	Values		Analog value	
	Decimal	Hexadecimal	High byte	Low byte
16	1	1_H	Sign 0 0 0 0 0 0 0	0 0 0 0 0 0 0 1

B.1 Representation of analog values

The following tables list the decimal and hexadecimal values (codes) of the possible current measuring ranges.

Table B- 2 Current measuring range 0 to 20 mA

Values		Current measuring range	Range
Dec.	Hex.	0 to 20 mA	
32512	$7F00_H$	> 23.518 mA	Overflow[2]
32511 . . 27649	$7EFF_H$ . . $6C01_H$	23.518 mA . . 20.0007 mA	Overrange
27648 . . 614	$6C00_H$ . . 266_H	20 mA . . 0.4442 mA	Nominal range
613 . . 1 0	265_H . . 1_H 0_H	< 0.4442 mA . . 723.4 nA 0 mA	Wire break[1]

[1] The F-module signals a wire break, $7FFF_H$ for S7-300/400 F-CPUs or 0 for S7-1200/1500 F-CPUs.

[2] In *STEP 7 Safety*, the fail-safe value 0 is provided in place of $7FFF_H$ (for overflow) in the PII for the safety program.

Table B- 3 Current measuring range 4 to 20 mA

Values		Current measuring range	Range	
Dec.	Hex.		Diagnostics wire break: No	Diagnostics wire break: Yes
32512	$7F00_H$	> 22.814 mA	Overflow[2]	Overflow[2]
32511 . . 27649	$7EFF_H$ . . $6C01_H$	22.814 mA . . 20.0006 mA	Overrange	Overrange
27648 . . 1 0	$6C00_H$ . . 1_H 0_H	20 mA . . 4 mA + 578.7 nA 4 mA	Nominal range	Nominal range
-1 . . -691	$FFFF_H$ . . $FD4D_H$	3.9994 mA . . 3.6 mA	Underrange	Underrange
-692 . . -6144	$FD4C_H$ . . $E800_H$	< 3.6 mA . . 0.4444 mA		Wire break[1]
-6145	$E7FF_H$	< 0.4444 mA	Underflow[2]	

[1] The F-module signals a wire break, $7FFF_H$ for S7-300/400 F-CPUs or 0 for S7-1200/1500 F-CPUs.

[2] In *STEP 7 Safety*, the substitute value 0 is provided in place of $7FFF_H$ (for overflow) or 8000_H (for underflow) in the PII for the safety program.